Swinney, D.A. (1979). Lexical access during sentence comprehension: (Re)consideration of context effects. *Journal of Verbal Learning and Verbal Behavior, 18*, 645–659.
Taft, M. (1979). Recognition of affixed words and the word frequency effect. *Memory & Cognition, 7*, 263–272.
Tanenhaus, M.K., Leiman, J.M., & Seidenberg, M.S. (1979). Evidence for multiple stages in the processing of ambiguous words in syntactic contexts. *Journal of Verbal Learning and Verbal Behavior, 18*, 427–440.
Taylor, S.E. (1962). *An evaluation of forty-one trainees who had recently completed the "reading dynamics" program* (11th yearbook of the National Reading Conference, pp. 41–55).
Thorndyke, P.W. (1977). Cognitive structures in comprehension and memory of narrative discourse. *Cognitive Psychology, 9*, 77–110.
Vesonder, G.T. (1979). *The role of knowledge in the processing of experimental reports.* Unpublished doctoral dissertation, University of Pittsburgh, Pittsburgh, PA.
Westheimer, G.H. (1954). Eye movement responses to a horizontally moving visual stimulus. *Archives of Ophthalmology, 52*, 932–943.

44

Modeling the Connections Between Word Recognition and Reading

Marilyn Jager Adams

Skillful reading is the product of an amazingly complex array of knowledge and abilities. How is it, then, that so much of the scientific literature on reading is centered on word recognition? One answer is that the field has lacked the scientific sophistication to go much beyond words; another, however, is that until we truly began to understand the relation of words to the rest of the reading process, we were hard pressed to move on.

True, the ability to recognize words is but a tiny component of the larger literacy challenge. Also true, the knowledge and activities involved in visually recognizing individual printed words are useless in and of themselves. And equally true, word recognition is only valuable and, in a strong sense, only possible as it is received and guided by the larger activities of language comprehension and thought.

On the other hand, unless the processes involved in individual-word recognition operate properly, nothing else in the system can either. The purpose of this article is to explore the relationship between word recognition and literacy. It is, moreover, to show how scientific efforts to understand these relationships have brought us ever closer to a larger understanding of the nature of reading.

The Operation of the Reading System

To clarify the relation of word-recognition processes to the rest of the system, an analogy might be useful. Let's say that the system that supports our ability to read is a car. Within this analogy, print is gas. The engine and the mechanics of the car are the perceptual and conceptual machinery that make the system run.

It is obvious that print is essential to reading—no gas, no driving. But print alone is not enough to make the reading car go. Reading cannot begin without

From Ruddell, R.B., Ruddell, M.R., & Singer, H. (Eds.), *Theoretical Models and Processes of Reading* (4th ed., pp. 838–863).

the spark of visual recognition. And just as cars are designed with more than one spark plug, so the reading system is designed to take in the physically separable pieces of print not one at a time, but in intricately coordinated concert. Like the crankshaft in a car, the reader's learned associations among letters and words keep the reading car rolling despite problems that might arise: The occasional letter that is misperceived or even illegible does not stop the reading machine any more than the occasional misfire of a spark plug or impurity in the gas will stop a car. Even so, the engine is only indirectly responsible for making the car go. The engine turns gas into kinetic energy, and the energy turns the wheels. Similarly, the perceptual system turns print to mental energy, such that it can be understood.

Obviously a car *couldn't* be driven without gas, without spark plugs, without a crankshaft, and without a differential and wheels. But it is also important to recognize that a car *wouldn't* be driven if it didn't run well. Imagine that you had to push a button every time you wanted a spark plug to fire. Imagine that the car would only go a couple of miles per hour or that it stalled unpredictably every few moments. You would very likely choose not to drive at all. These problems are analogous to the difficulties that must befall the reader who cannot transform print to language and meaning with reasonable speed and ease. In particular, if a child's word-recognition skills are sufficiently poor, the time and effort involved in reading may well overwhelm its hoped-for rewards. If so, the child is likely to choose not to read at all. And here is the tragedy: To the extent that children do not read, they forfeit the practice and experience needed to make reading easier and more profitable. To the extent that children do not read, they can only continue to have difficulty reading, to fall farther and farther behind their peers in both reading and the conceptual returns it offers (see, especially, Stanovich, 1986, 1993).

Clearly, without gas and without an engine and mechanics in adequate working order, the car will not go. Suppose, however, that your reading system has plenty of print to consume and a fine mechanical system. Are you on your way? No. First, you have to want to go somewhere, and you have to have some idea of how to get there. As you travel, you must monitor and control your path. Periodically, you must assess your whereabouts and progress with respect to your final destination. At the same time, you must attend to the local details of the road and control your car through them. Indeed, the amount of active attention you will have to devote to your immediate progress will necessarily depend on such variables as the navigability of the route—how far you can see ahead and whether the way is bumpy, winding, congested, or unpredictable—and its familiarity.

Similarly, if texts are difficult in wording or structure or unfamiliar in concept, they require the active attention of the reader. But the more one must direct attention to local difficulties of reading, the less attention one has available to support larger understanding. Only to the extent that the ability to recognize and capture the meaning of print is rapid, effortless, and automatic can the reader have available the cognitive energy and resources on which true comprehension depends. Only to that extent can the reader have the perspective and capacity to reflect upon the journey.

As it happens, *everybody* wants to go somewhere. Everybody wants the stimulation of new challenges and the sense of growth and accomplishment that comes with conquering them. Understandably, if reading seems tedious or unproductive, children will seek other ways to spend their time; indeed, they may avoid it altogether. In a recent survey of fourth graders, 40% of the poor readers claimed that they would rather clean their rooms than read. One child stated, "I'd rather clean the mold around the bathtub than read" (Juel, 1988).

Fortunately, for purposes of schooling, most young children will go almost anywhere they are led—so long as they are neither frustrated nor bored. But even as this eases our task as reading educators, it greatly increases our responsibility. It is up to us to lead our children in the right direction.

And it is here that the car analogy breaks down. So apt for describing the operation of the system, it is wholly inappropriate for modeling its acquisition. Building a car is a modular, hierarchical activity. From the bottom up, the discrete and countable parts of the car's subsystems are fastened together; then, one by one, from the inside out and only as each is completed, the subsystems are connected to one another. In contrast, the parts of the reading system are not discrete. We cannot proceed by completing each one in isolation and then fastening it to another. Rather, the parts of the reading system must grow together. They must grow to and from one another.

For the connections and even the connected parts to develop properly, they must be linked in the very course of their acquisition. And this dependency works in both directions. We cannot properly develop the higher-order processes without due attention to the lower; nor can we focus on the lower-order processes without constantly clarifying and exercising their connections to the higher.

The great challenge for reading educators, therefore, is one of understanding the parts of the system and their interrelations. In this article, I will focus on current models of skillful readers. What special kinds of knowledge do skillful readers have? How is it organized and what are the processes that bring it into play? And how does our evolving understanding of skillful readers help us understand the learning process and its difficulties?

What Do Skillful Readers Do?

Perhaps the single most striking characteristic of skillful readers is the speed and effortlessness with which they breeze through text. The rate at which they read typically exceeds five words per second (Rayner & Pollatsek, 1987). Indeed, they appear to recognize whole words at a glance, gleaning their appropriate meaning at once (Cattell, 1885). How do they do so?

Some Questions

Do skillful readers, in fact, recognize words as wholes? In recognizing an individual word, do readers depend on its overall pattern or shape rather than any closer analysis of the letters within it? If so, then doesn't it seem counterproductive to train children to focus on the letter-by-letter spellings of words?

Do skillful readers access the *meaning* of a word directly from seeing it? If so, then doesn't it seem counterproductive to teach children to sound words out?

Do skillful readers use context to anticipate upcoming words so as to reduce the visual detail they need from the text? If so, then in place of rigorous decoding instruction, wouldn't it be better to teach children to use context together with such minimal distinguishing cues of words as first letters and overall length?

Do skillful readers use context to anticipate the words they will see, such that their comprehension consists as much of confirming as of interpreting their meanings? If so, then shouldn't a central focus of beginning reading instruction be one of discouraging children's tendency to pore over the separate words in text and of strengthening their ability to guess the words instead?

Some Answers From Research

Each of these notions has been seriously entertained by researchers at one time or another, and the instructional implications of each are realized prominently in many curricula and classroom practices. Under scrutiny, however, each of these notions has been proved incorrect. More than that, each has been proved incorrect in ways that strongly argue against their instructional translations.

As it turns out, research has long shown that skillful readers are relatively indifferent to the shapes of the words they read (see Woodworth, 1938). Even when the letters that make them up are randomly sampled from a variety of type styles and sizes in both uppercase and lowercase fonts, skillful readers seem to recognize familiar words as wholes (Adams, 1979a). At the same time, skillful readers visually process virtually every letter of every word as they read; this is true whether they are reading isolated words or meaningful, connected text—and, surprise of surprises, it is even true when they are reading cursive handwriting (De Zuniga, Humphreys, & Evett, 1991). To be sure, skillful readers rarely think about individual letters or words as they read. At a conscious level, they may not even notice flagrant misspellings or misprints. But studies show that, conscious or not, letter recognition is integral to the reading process and that even the slightest misprint, tucked deep within a long and highly predictable word, tends to be detected by the visual systems of skillful readers; detection is signaled by readers' eyes flicking back to the misprint to make sure the type was seen correctly (McConkie & Zola, 1981).

Research also negates the notion that skillful readers use contextual guidance to preselect the meanings of the words they will read. Consider the following sentences:

They all rose.

John saw several spiders, roaches, and bugs.

The last word of each of these sentences is, in itself, ambiguous—but would you have noticed if that hadn't been pointed out? Although it feels as though context preselects the appropriate meanings of such words, that is not exactly what happens. Research demonstrates that all the meanings of an ambiguous word are aroused in the course of perception. Very shortly (within tenths of a second) thereafter—too quickly for us to become aware of the confusion—context selects the most appropriate meaning from among the alternatives. (For a review of research in this area, see Seidenberg et al., 1982.)

Finally, research proves that skillful readers habitually translate spellings to sounds as they read (see Barron, 1981a, 1981b; Patterson & Coltheart, 1987). But why? If visually familiar words do indeed activate their meanings directly for readers—and they do—then of what conceivable value are such phonological translations? The answer to this question has come only through many years of work and many research studies: Such spelling-to-sound translations are vital to both fluent reading and its acquisition. To see why, we must look more deeply into the reading system.

Modeling the Reading System: Four Processors

The purpose of models is to combine findings from many studies into a single, coherent system. Because a usefully detailed model lays bare those spots where assumptions are not supported by research, it is an extremely valuable scientific tool. In particular, where the model's pieces seem to fit in more than one way or not to fit at all, the researcher must conclude that some assumption is awry or that some important consideration has been overlooked. Gradually, through the cyclical process of modeling, assessing, and gathering new data, researchers gain an ever more refined and complete image of the parts of a system and how they must work together.

By developing more comprehensive models of the nature of the reading system and the interrelations of its parts, researchers have strived to understand the reading process as a whole. Anchored in psychological research and built through laboratory studies and simulations, contemporary models of reading are complex. However, it is because they have been developed with such analytic care that their instructional implications carry special weight.

Indeed, because they move beyond the boundaries of our field to exploit advances in logical, mathematical, and computational sciences, recent models appear provocatively capable of mimicking the processes of reading and learning

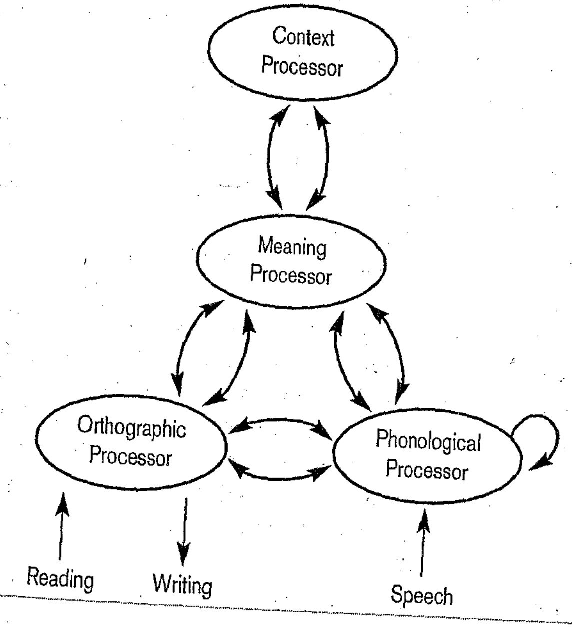
to read. These newer models, alternatively known as connectionist, neural net, or parallel distributed processing (PDP) models, are built on the assumption that learning progresses as the learner comes to respond to the relationships among patterns or events. It is, for example, the overlearned relations among its sides that enables recognition of a triangle, just as it is the overlearned relations among its letters that enables recognition of a word. Similarly, it is the relations among the pitch, timing, and quality of its notes that evoke interest in a piece of music, just as it is the relations among the meanings of its words that give texture and meaning to a sentence. (For a description of the logic and dynamics of these models, see Rumelhart & McClelland, 1986; for an exploration of their pertinence to reading, see Adams, 1990, and Seidenberg & McClelland, 1989; for a discussion of their general importance and potential, see Bereiter, 1991).

The power of these models derives from the fact that they are neither top down nor bottom up in nature. Instead, all relevant processes they include are simultaneously active and interactive; all simultaneously issue and accommodate information to and from one another. The key to these models, in other words, is not the dominance of one set of processes over the others, but the coordination and cooperation of all as shaped by the reader's own prior knowledge and experience.

As adapted to the reading situation, the grand logic of these models is schematized in Figure 1 (see Adams, 1990, for a fuller description and discussion). Within each of the "processors," knowledge is represented by many simpler units that have become linked to, connected with, or associated with one another through experience. The oval labeled *orthographic processor*, for example, represents the reader's knowledge of the visual images of words. Within it, individual letters are represented as interconnected bundles of more elementary visual features, while printed words are represented as interconnected sets of letters. Similarly, the meanings of a familiar word are represented in the meaning processor as bundles of simpler meaning elements, just as its pronunciation is represented in the phonological processor as a complex of elementary speech sounds.

I introduced the term "processors" in quotation marks so as to emphasize that it is mostly for descriptive convenience that the different types have been separated one from another. The associations among pieces of knowledge depend not on the "processor" in which each resides, but on the ways in which they have become interrelated or connected through experience. Indeed, the links among any set of representational units are nothing more than a cumulative record of the ways in which those units have been related to one another in a person's experience. The more frequently a pattern of activity has been brought to mind, the stronger and more complete will be the bonds that hold it together. Ultimately it is these bonds, these interrelations—as they pass excitation and inhibition among the elements that they link together—that are responsible for the fluency of the reader and the seeming coherence of the text.

FIGURE 1
Modeling the Reading System: Four Processors



For the skillful reader, as the letters of a word in fixation are recognized, they activate the spelling patterns, pronunciations, and meanings with which they are compatible. At the same time, using its larger knowledge of the text, the context processor swings its own bias among rival candidates so as to maintain the coherence of the message. Meanwhile, as each processor homes in on the word's identity, it relays its progress back to the others such that wherever hypotheses agree among processors, their resolution is speeded and strengthened.

In this way, speed and fluency are seen as an emergent property of the mature reading system. With recognition initiated by the print on the page and hastened by the connectivity both within and between the processors, skillful readers access the spelling, sound, meaning, and contextual role of a familiar word almost automatically and simultaneously. But note: Speed and fluency are not just an outgrowth of skillful reading; they are necessary for its happening. To understand better the knowledge and processes involved, let us examine each of the processors in turn.

The Orthographic Processor

To be fluent and productive, reading depends no more on recognizing words than on astute and flexible consideration of the linguistic and conceptual contexts in

which they occur. Indeed, the whole point of the model outlined above is that, in skillful reading, the mind works interactively and in parallel with as many cues and clues as it can recognize as relevant.

Nevertheless, as illustrated in Figure 1, the orthographic processor alone receives information directly from the printed page. By implication, the letters and words of text constitute the basic perceptual data of reading, and this is as it should be. After all, the words on the page are authors' principal means of conveying their message. It will not do for readers to ignore them, nor will guessing suffice: Even skillful adults are unable to guess correctly more than 25% of the time (Gough, Alford, & Holley-Wilcox, 1981).

For skillful readers, meaningful text is read through what is essentially (in English) a left-to-right, line-by-line, word-by-word process. In general, skillful readers visually process virtually each letter of every word they read, translating print to speech as they go. They do so whether they are reading isolated words or meaningful, connected text. They do so regardless of the ease or difficulty of the text, regardless of its semantic, syntactic, or orthographic predictability. There may be no more broadly or diversely replicated set of findings in modern cognitive psychology than those that show that skillful readers visually process nearly every letter and word of text as they read. (For reviews, see Adams, 1990; Patterson & Coltheart, 1987.)

Eye movement research informs us that our eyes do not move smoothly through the lines of text while we read. Instead, they leap from word to word, fixating briefly toward the center of each and then jumping to the next. Occasionally, readers do skip a word, but almost never more than one. Further, the words that are skipped tend rather exclusively to be short function words such as *of*, *a*, and *to*. Many function words and the vast majority of content words receive readers' direct gaze. (For a review, see Just & Carpenter, 1987.)

With normal print, the eye can clearly resolve up to three or so letters to the left of its fixation point and about twice that many to the right during each fixation. With these letters as its basic data, the system goes to work. To see how it proceeds, let us consider two examples. First, suppose the reader's eye lands on the word *the*. Because *the* is a frequently occurring and familiar word, all of its letters should be strongly interconnected within the reader's orthographic memory. As the reader looks at the word, the units corresponding to each of the letters receive visual stimulation from the page. Because the units are so strongly interconnected in the reader's memory, each will pass stimulation to the others, causing all to be recognized nearly at once and to hang together in the reader's mind as a familiar, cohesive spelling pattern.

Now suppose instead that the eye lands upon the nonword *tqe*. Because this string of letters is so similar to the word *the*, the reader's orthographic memory will attempt to process it in the same way. That is, the *t* and *e* units will pass stimulation to each other; they also will pass stimulation to the *h* unit. This time,

however, because the *h* receives no direct visual stimulation, it cannot pass any back. At the same time, because *q* is almost always followed by *u* in English, the *q* unit will pass its stimulation to the unit for the absent *u*. As the directly stimulated letter units send their activation inappropriately around the letter network, they end up hurting rather than helping one another's progress. Eventually the direct visual stimulation from the page will bring each of the presented letters to peak stimulation, and the reader will see the string as printed: *tqe*. However, the perception of each letter will have taken longer and will have gelled independently of the others (McClelland & Rumelhart, 1981).

Through experience, the associative network comes to respond not just to next-door neighbors but also to the larger sequences and patterns of letters that represent whole, familiar words. And eventually, through its overlapping representation of many, many different words, it becomes responsive to common spelling patterns independently of the particular words in which they occur. Ultimately, it is the learned associations between and among individual letters that are responsible for the easy, holistic manner in which skillful readers respond to printed words. It is because of them that familiar words and spelling patterns are easier to read than the sum of their parts.

Yet the interletter associations provide other services that are of equal importance to the reader. These services include processing letter order and breaking words into syllables.

Processing Letter Order. Although the visual system is remarkably efficient at extracting information necessary for letter identification, it is quite sloppy about processing letter order. This is a physical limitation, affecting skillful readers as much as unskilled ones (Estes, 1977). Nevertheless, skillful readers almost never make mistakes in reporting the order of the letters in words they read; poor readers, in contrast, may often do so. Although letter-order difficulties were once taken as symptomatic of a basic perceptual deficit, that explanation has been proven incorrect (Liberman et al., 1971). Such difficulties seem instead to reflect insufficient orthographic learning. Specifically, among skillful readers, knowledge about the likely ordering of a string of letters is captured in the learned associations between them. In the very course of perception, therefore, this knowledge serves to corroborate the sensory system's noisy transmission of letter order. In keeping with this view, good readers rarely err in reporting the order of the letters in either real words or regularly spelled nonwords (such as *bome* or *mave*). Yet when faced with orthographically irregular strings such as *gtsi* or *ynrh*, they make just as many ordering errors as do poor readers—even more if they were expecting to see a regularly spelled string (Adams, 1979b).

There are several ways in which readers can conquer the letter-order problem even without well-developed interletter associations. One is to stick with print that is sufficiently large and spaced out so that no two letters will share the

same physical input channel; no doubt this is the underlying reason for our time-honored practice of setting primers in large type. Another is for readers to increase the number or duration of their fixations on each word. In keeping with this, note that prolonged and repeated fixations on words are characteristic of young and disabled readers (Just & Carpenter, 1987). In the long run, however, the only efficient and reliable way around this difficulty is for readers to learn more about likely and unlikely sequences of letters in the words of their language. Eventually, this knowledge will come to compensate for the visual system's inherent difficulty with letter order.

Breaking Words Into Syllables. Struggle as they might, poor readers characteristically block on long, polysyllabic words—even when those words are familiar within their oral vocabulary. In contrast, skillful readers rarely experience such difficulty. As an example, try reading the following: *trypsinogen, anfractuosity, prolegomenous, interfascicular.* Although none of these words may be familiar to you, chances are that your attempts to read them were relatively forthcoming as well as correct, or nearly so. Moreover, if you listened carefully to your reading performance, you may have heard yourself producing them in a manner much closer to syllable by syllable than holistically or letter by letter.

It turns out that skillful readers' ability to read long words depends inseparably on their ability to break the words into syllables (Mewhort & Campbell, 1981), and this is true for familiar as well as unfamiliar words. Laboratory studies prove that skillful readers break words into syllables automatically and in the very course of perceiving their letters. The means by which skillful readers do this are again rooted in their overlearned knowledge about likely and unlikely sequences of letters. More specifically, for any language that is basically alphabetic, strings of speech sounds that can be coarticulated tend to be represented by frequent sequences of letters, while those that cannot, are not. As an example, the spoken sequence /dr____/ is a frequent and pronounceable form in English—as in *drag, dress, drip,* and *drove*—while /dn___/ is not. Consistent with this, the letter sequence *dr*___ is 40 times more likely to occur in print than the sequence *dn*___ (Mayzner & Tresselt, 1965). Through the learned associations in the reader's letter-recognition network, the letters *d* and *r* will automatically boost each other's perceptibility when seen in print, while the letters *d* and *n* will not.

The importance of this difference is that, although unlikely letter sequences such as *dn* cannot occur within the same syllable, they can and do occur at syllable boundaries (for example, *midnight, baldness, kidnap, Sidney*). As the reader processes such words, the likely combinations of letters promote and attract one another, emerging perceptually as a cohesive spelling pattern. At the same time, however, the unlikely pairs inhibit and repel each other, thus pushing separate syllables apart. As a result, the perceived letters are tightly bound to one another within syllables but somewhat detached at the boundaries between syllables. In this way, polysyllabic words are perceived as sequences of spelling patterns corresponding to syllabic units.

At this point, a word of caution is warranted. The knowledge underlying automatic syllabification skills cannot be directly instilled. To ask children to study unlikely letter pairs would be counterproductive: It would serve to increase the strength of the associations between such letters in memory, which is just the opposite of what is needed. Beyond that, one cannot hope to specify spelling patterns corresponding to syllabic units or their boundaries independent of the larger orthographic context in which they occur. That is, one cannot take any given letter string—say, *par*—and proclaim it to be a syllabic unit. Sometimes it will be (*par-tial, par-take*), and sometimes it will not (*part-ly, pa-rade*). In syllabifying words, the orthographic processor responds to the relative strengths of the interletter associations (Adams, 1981; Seidenberg, 1987). Using knowledge of simple letter sequences as well as larger letter patterns (for example, *fa-ther* versus *fat-head*), it breaks a word into syllables not at predesignated junctures but at the weakest link between letters. It can do so only to the extent that the reader has acquired a broad and deep knowledge of orthography. Meanwhile, there is much to recommend that oft-used technique of helping children penetrate those troublesome long words by uncovering them syllable by syllable as they read.

Helping Beginners. Before leaving this section, it is worth reflecting that all the orthographic processor's magic presumes a deep and ready knowledge of the letterwise spellings of words. Quick, holistic word recognition, comfort with grown-up–sized print, automatic syllabification, morphemic sensitivity—all of these depend on such knowledge. At the same time, research indicates that difficulties at the level of letter and word recognition are the single most pervasive and debilitating cause of reading disability (Perfetti, 1985; Stanovich, 1986; Vellutino, 1991; Vernon, 1971).

Fortunately, theory and research also affirm that human memory is well designed for learning about such relations among letters—but only if it is induced to attend to them in the course of perception. Here, then, is a problem. In general, children seem disposed to view words not as ordered and analyzable strings of letters but holistically, rather like pictures (Byrne, 1992; Masonheimer, Drum, & Ehri, 1984). Indeed, given a good visual memory, children have shown themselves able to recognize several thousand words through this approach (Juel, 1991). But can they learn 50,000? And when they find they cannot, how difficult—cognitively and emotionally—will it be to effect repairs?

Beginning reading is quite difficult for some children. One of the reasons is surely that the knowledge to respond instantly, effortlessly, and accurately to frequent words and spelling patterns involves an impressive amount of perceptual learning. Regardless of intelligence, effort, rearing, or desire, this learning

settles in more quickly for some children than for others. There are many ways to support this learning—including writing, spelling, and phonics instruction; patience; encouragement; and lots of beneath–frustration-level reading and rereading. However, research argues firmly that there is no substitute for it.

The Context Processor

The context processor is in charge of constructing a coherent, ongoing interpretation of the text. In particular, it is responsible for priming and selecting word meanings that are appropriate to the text. This is important not just for blatantly ambiguous words (such as *soccer ball* versus *inaugural ball*) but, to a lesser extent, for almost any word.

As an example, consider the word *Wyoming*. People in the United States might consider *Wyoming* to have a unique and stable meaning as a proper noun. Nevertheless, its mention brings very different images to mind in a discussion of presidential campaign strategies and electoral college votes than it does in a discussion of beautiful national parks. In fact, both of these images—and many more besides—are part of the total array of meaning that each of us associates with the word *Wyoming*. We are able to follow discussions of Wyoming with understanding because the context processor selectively emphasizes those aspects of a word's total meaning that are relevant to its ongoing interpretation.

In theory, the context processor works by sending its own stimulation to the meanings that it expects. This extra stimulation boosts the contextually appropriate dimensions of a word's meaning, causing them to dominate the reader's interpretation of the text. Yet even while the context processor facilitates the reader's awareness of appropriate words and meanings, it does not prevent stimulation of inappropriate ones. To use an earlier example, given a sentence such as *John saw several spiders, roaches, and bugs*, people very briefly show signs (but not conscious awareness) of having interpreted the last word to mean both "insects" and "spying devices" (Seidenberg et al., 1982). Alternatively, given a sentence such as *At the farmstand, we got tomatoes, squash, and corn on the* ___, the reader may quite automatically—thanks to the context processor—expect the word *cob*. But if the complete sentence turns out, instead, to read, *At the farmstand, we got tomatoes, squash, and corn on the car*, that expectation would be quickly overridden. And, nearly as quickly, the context processor would also revise the reader's understanding of the situation so it meets the text.

For skillful readers, the role of context is not to displace or supplant the information on the page; it is, instead, to help the reader make the most of that information, as quickly and efficiently as possible. To that end, it is necessarily the author's words that must take precedence. Consistent with this, study after study has shown that context significantly affects the speed or accuracy with which skillful readers perceive familiar words *only* when the experimenter has done something to slow or disrupt the orthographic processing of the word (see, e.g., Stanovich, 1980, 1984).

Provided that a text is not too difficult, beginners, like skillful readers, are naturally attuned to its linguistic and semantic flow as they read. Further, as long as the stories are simple and until the processes involved in visual word recognition are fairly well developed, many readers find that they often can guess the identity of a word as accurately and more easily than they can decode it. For these reasons, it has been found that among young and disabled readers, word-recognition performance is especially sensitive to context and contextually appropriate substitution errors are frequent (see, e.g., Biemiller, 1970; Weber, 1970).

Although such sensitivity to context can only be a good sign, its dominance is a symptom that orthographic processing is proceeding neither quickly nor completely enough to do its job. But, one might ask, is this reason for concern? If the children are grasping the meaning of the text well enough to fill in the blanks, then clearly they are reading thoughtfully and strategically. If so, is there any reason to intervene?

As you ponder these questions, I ask you to add the following consideration. As the purpose of classroom texts shifts from one of learning to read to one of reading to learn, children will increasingly encounter words they do not recognize in contexts that do not help. Very often, however, it will be precisely these unknown words—*isosceles*, *circumference*, *photosynthesis*, *Antarctica*, *equator*—that are most central to the point of the lesson.

Research shows that as children move a little further into the reading process—usually toward the end of first grade or the beginning of second—they often turn what seems disproportionate attention to the individual words on the page. Suddenly, they start reading *there* for *three*, *was* for *saw*, and *from* for *form*; the effort they invest in reading a word seems unrelieved by the most obvious of contextual cues; their misreadings, while graphically related to the print on the page, may often be wholly inappropriate in context; and they may develop a tendency to stare at difficult words without responding at all.

For different children, these tendencies may be more or less pronounced and may persist for longer or shorter periods. Nevertheless, as Downing (1979) explains, these tendencies reflect a necessary and highly functional phase in the acquisition of any complex skill. The only way for the visual system to learn about the spellings of words is by devoting attention to them. As the spellings of more and more words are internalized, decoding will become more and more automatic, and only when it becomes automatic can it properly work in concert, rather than in competition, with contextual processing. Meanwhile, the instructional challenge is not to quash this phase but to help children through it as efficiently, effectively, and supportively as possible. To this end, there may be no better means than encouraging a lot of reading and rereading of interesting and beneath–frustration-level text.

The Meaning Processor

The inner workings of the meaning processor appear similar to those of the orthographic processor. In particular, the units in the meaning processor apparently do not correspond to whole, familiar words. Instead, just as the spellings of familiar words are represented in the orthographic processor as interassociated sets of letters, their meanings are represented in the meaning processor as interassociated sets of more primitive meaning elements. It is this piecemeal nature of word meanings that allows us to focus on one aspect or another of a word's full meaning as appropriate in context. In addition, it enables us to acquire the meaning of new words gradually by encountering them in context.

Learning New Word Meanings From Context. Suppose that, while reading a story, a child encounters a word that he or she has neither seen nor heard before. As usual, the spelling and pronunciation of this word will be shipped automatically to the meaning processor, but because the word is entirely unfamiliar, it cannot in itself evoke any particular meaning. Instead, when the word reaches the meaning processor, all it will find is the pattern of activation provoked by the context processor. This pattern may be more or less diffuse, depending on how tightly the context has anticipated the unknown word. Nevertheless, when the orthographic pattern meets these activated meaning units, a bond will begin to form between them.

The impact of such an incidental learning experience is expected to be small: Context is rarely pointed enough to predict the precise meaning of a word. On the other hand, it's a start. When the same word is encountered again, it will meet whatever was learned from the prior context plus the meaning set off by the new context. Wherever the meaning units of the old and new contexts overlap, they will become more strongly associated with one another and with the orthographic and phonological representations of the word. Given a number of encounters with this word over a variety of different contexts, the units that are reinforced most often will be those that belong to the meaning of the word itself. In this way, the word may eventually be learned well enough to contribute independently and appropriately to the meaning of a text, if not to allow the child to generate a well-articulated dictionary definition.

Although important, such learning from context is inherently gradual and imprecise. The likelihood that a child will learn the meaning of a word from a single exposure in meaningful context ranges from 5% to 20% (Nagy, Anderson, & Herman, 1987). By implication, the extent of such incidental vocabulary acquisition depends strongly on the amount a child reads. The average fifth grader is estimated to read about 1 million words of text per year: 650,000 out of school and the rest in school (Nagy, Herman, & Anderson, 1985). Of these words, roughly 16,000 to 24,000 will be unknown (Anderson & Freebody, 1983). Conservatively assuming a 5% chance of learning each, the result is a vocabulary increase of 800 to 1,200 new words each year through reading. Learning from context accordingly accounts for a substantial fraction of the 3,000 new words that children are, on average, expected to master each year (Miller & Gildea, 1987).

This research sheds light on some of the most striking differences observed in children's conceptual growth. The estimates above are based on the average reader. Some children read millions and millions of words of text each year; their vocabularies are expected to be strong. At the same time, others read practically nothing at all outside of school. Over all, Nagy, Anderson, and Herman (1987) estimate that the 90th percentile student reads about *200 times* more text per year than the 10th percentile student does. Learning begets learning. The amount that children read influences not only their vocabulary growth but also the conceptual and linguistic knowledge that enables that growth and makes it useful.

Direct Vocabulary Instruction. Beyond such learning through reading, direct vocabulary instruction has been shown to result in a general increase in both word knowledge and reading comprehension (Stahl & Fairbanks, 1986). To be most effective, such instruction should include a number of examples of the word's usage in context in addition to definitional information. Research has shown that in direct vocabulary instruction as in incidental learning, the number of times children encounter a word is a strong predictor of how well they learn it. But almost as important as the number of encounters is the richness and variety of the contexts in which the word appears. Of particular interest is the finding that through rich and diverse experiences with a word, children appear to gain a special advantage in understanding its connotations or submeanings in specific contexts and in exploiting its extended meaning in text comprehension (McKeown et al., 1985).

Prefixes, Suffixes, and Roots. The direct link between the orthographic and meaning processors also may be responsible for skillful readers' perceptual sensitivity to the roots and affixes of polysyllabic words (see Fowler, Napps, & Feldman, 1985; Manelis & Tharp, 1977; Taft, 1985; Tyler & Nagy, 1987). Moreover, this link prompts the idea that teaching children about derivational morphologies might be a useful step toward both spelling and vocabulary development.

For example, once one sees that *concurrent* consists of "with" (*con-*) plus *current*, the word is no longer a spelling problem; it must have two *r*s as in *current*, and it can't end in *-ant* or it would mean *with a raisin*. Conversely, knowing the meanings of common roots may qualitatively and profitably change one's understanding of other words in their derivational family. Thus, learning that *fid* means "trust" or "faith" may significantly alter and connect one's understanding of words such as *confidence*, *fidelity*, *fiduciary*, and *bonafide*; discovering that *path* means "suffering" may alter and connect one's understanding of words such as *sympathy*, *psychopath*, and *pathologist*. Moreover, a well-developed sensitivity to morphological clues may be useful for inferring the meanings of new words.

All such advantages notwithstanding, research demonstrates that adult readers of English are surprisingly oblivious to the morphological structure of words (Kaye & Sternberg, 1982), and efforts specifically intended to teach children about the derivational morphologies of words have yielded mixed results (Johnson & Baumann, 1984; Otterman, 1955). Although such lessons have been shown to increase children's proficiency with both the spellings and meanings of the words studied, they have produced little increase in their ability to interpret new derivationally complex words.

In the end, it may be that such morphologically based insights never come automatically but only through deliberate search. Perhaps the wordsmith's advantage is principally strategic; he or she has learned to examine each new word for familiar parts and to think about their implications with respect to the word's usage and meaning. If so, then perhaps the objectives of our lessons on derivationally complex words should be rethought. Perhaps instead of teaching children about any particular sets of roots or affixes, our objective should be one of developing children's *awareness* of word structure and their inclination to look for and think about such relations in new words.

As an inspiring example of the promise of this approach, I refer you to a monograph by O'Rourke (1974). As O'Rourke led his students to make a habit of seeking, comparing, contrasting, and categorizing the meanings and spellings of complex words, their measurable vocabulary scores increased quite dramatically. In addition, showing that these lessons had affected not just their knowledge of particular words but also their thinking about them, the children tended to create new words to suit their expressive needs while writing—for example, *jector* (hurler), *tracted* (pulled, hauled), *audict* (someone who likes to hear records), *intraction* (pulling from within), *solarscope* (sun viewer), *phonomatic* (something that makes sounds by itself), *astrometer* (a device that measures stars). While some of these words are endearingly funny, others are soberingly legitimate.

In any case, it also may be wise to recognize that word roots and syllabic units rarely coincide. In terms of syllables, for example, the word *information* may be parsed into *in-for-ma-tion*; in terms of morphemes, it is *in-form-ation*. Research has demonstrated that the spelling patterns to which children are asked to attend during instruction significantly influence the patterns to which they do attend during word recognition (Juel & Roper/Schneider, 1985). Research also indicates that, for purposes of facilitating word recognition, it is familiarity with patterns that occur in a large variety of words that is most helpful (Juel, 1983). Thus, while appreciation of the *form* in *information* might shed light on its deeper meaning, familiarity with the *for* will help a reader read more words. The suggestion is that even when and if the worth of lessons on derivational morphology is firmly demonstrated, such instruction may nevertheless be best postponed until later years of schooling.

In summary, the most important point of this section is that meaningful experiences with words are important to the acquisition of the words' usage and interpretation as well as their orthography. The best way to foster children's visual vocabulary—as well as their larger literacy growth—is to have them read as frequently, broadly, and thoughtfully as possible. It is not merely that such reading results in vocabulary growth but that, more important, it affords children the conceptual and linguistic experience that at once enable that growth and make it worthwhile.

The Phonological Processor

Intuition suggests that visually familiar words can be recognized immediately and directly by sight, with no need for sounding out at any level. Consistent with this, research affirms that skillful readers do not depend on phonological translations for recognizing familiar words (see Spoehr, 1981). On the other hand, skillful readers automatically and rather irrepressibly seem to produce such translations anyway (Perfetti, Bell, & Delaney, 1988; Tannenhaus, Flanigan, & Seidenberg, 1980; VanOrden, 1991). Far from being unnecessary, the phonological loop provides invaluable support to the reader. First, it provides a redundant processing route—a back-up system—for the orthographic processor. Second, it provides critical support for the comprehension process as it effectively increases the reader's running memory for text. Without the added assistance of the phonological processor, even the most skillful readers would find themselves faltering for fluency and comprehension except with the easiest text.

As with the other processors, the phonological processor is seen to contain a complex network of units. The auditory image of any particular word, syllable, or phoneme corresponds to the activation of a particular, interconnected set of those units (McClelland & Elman, 1986). Figure 1 shows how readers' phonological knowledge and processes are related to the rest of the reading system. Note especially how the phonological processor is connected in both directions to the orthographic processor and the meaning processor. The arrow that runs from the orthographic to the phonological processor indicates that, even as the orthographic processor begins to resolve the image of a string of letters, it relays stimulation to corresponding units in the phonological processor. Meanwhile, the activation of a word's pronunciation will, in turn, pass stimulation to its meaning, as symbolized by the arrow running from the phonological to the meaning processor. In this way, the connections through the phonological processor provide a means for identifying words that, although visually unfamiliar, are in the reader's speaking or listening vocabulary. Yet that is only their most immediate and obvious advantage.

To the extent that any word is both orally and visually familiar, this process ensures that the meaning processor will receive activation from *both* the phonological and the orthographic processor. As these contributions support and interact

with one another, they serve to ease and speed recognition of the word. Further, as the response of the meaning processor is strengthened and focused, so too is the activation that it passes back to the other processors—and the stronger the feedback, the greater the learning. Thus, the contributions of the phonological processor act to hasten and consolidate the direct connections between all the processors, and that includes the *direct* connections between sight and meaning.

The connections running from the phonological processor back to the orthographic processor are equally important in supporting visual learning. Specifically, where the efforts of the orthographic processor arouse pronounceable responses in the phonological processor, the phonological processor will reciprocally send excitation right back. In this way, the feedback from the phonological processor provokes the orthographic processor to attend to letters that might otherwise be overlooked, even while helping it glue the whole, correctly ordered string together. The prior knowledge and constraints offered by the phonological processor play an indispensable role in helping young readers organize, consolidate, and remember spelling patterns visually.

Finally, note that there is also an arrow running from the meaning processor to the phonological processor in Figure 1. Because of this connection, the activation of a word's meaning will send stimulation to the phonological units corresponding to its pronunciation. The reader's tendency to translate print to speech is thus doubly stimulated, both from the word's spelling and from its meaning. This is one reason that phonological translation of print is so automatic—and beyond that, it completes the circularity and feedback of the system in both directions. It is this circularity and feedback that ultimately underlies the automaticity of the word-recognition system. Because of this circularity, the responses of all the processors speed and support one another wherever they are consistent; wherever they are inconsistent, they are automatically corrected or flagged for special attention.

The phonological processor has two other features that set it apart from the others. First, like the orthographic processor, the phonological processor accepts information from the outside, although the information it accepts is speech. (The orthographic processor remains the only one to receive information directly from the printed page.) Second—and this turns out to be an important asset in reading—the knowledge represented within the phonological processor can be activated at will. We can speak, subvocalize, or otherwise generate speech images whenever we wish.

Phonological Translation and Fluent Word Recognition. As shown in Figure 1 and supported by our intuitions, phonological translation is not always necessary for word recognition. As reflected by the direct connections between the orthographic and meaning processors, visually familiar words can be recognized and understood with no need of phonological translation. Yet a word can map instantly, effortlessly, and accurately from sight to meaning only to the extent that its unique, ordered sequence of letters has been visually learned and overlearned through experience. The problem is that printed words vary enormously in their frequency and, therefore, in their visual familiarity to a reader.

Analyses of the everyday reading matter of adults reveal that the vast majority of print consists of relatively few, very frequently occurring words (Kučera & Francis, 1967). Because each of these words is highly familiar to the skilled reader, each is recognized quickly and easily. However, these oft-repeated words account for but a small fraction of the number of different words readers encounter. The vast majority of distinct words in print are relatively infrequent—occurring less than once in every million words of running text. Because these words are so rarely seen, the reader's visual familiarity with most of them must be relatively weak and incomplete—often too weak and incomplete to support the perceptual speed and automaticity on which comprehension depends.

Word counts of children's reading materials reveal a similar pattern. Fifty percent of the print they are likely to see, in school and out, is accounted for by only 109 different words, 90% by only 5,000 different words (Carroll, Davies, & Richman, 1971). It is reasonable to suppose that not too far into their schooling, most children will be quick to recognize most of these words by sight. But how are they to cope with the tens of thousands of other words they see? It will not do to skip such words or guess at their identities. Although the coherence of a text depends strongly on its frequent words—*it, that, this, and, because, when, while*, and so on—the information in a text depends on its less-frequent words—*doctor, fever, infection, medicine, penicillin, Alexander Fleming, melon, mold, poison, bacteria, antibiotic, protect, germs*, and *disease*, for example. For skillful readers, automatic phonological translations provide a back-up system for recognizing visually less-familiar words. As a consequence of the alphabetic principle, syllables are represented by frequent spelling patterns. For the skillful reader, therefore, even if a word as a whole is not visually familiar, fragments of its spelling most certainly will be. Because of the reader's spelling–sound associations, these spelling patterns will be translated automatically to their phonological equivalents. If the word is in the reader's speaking or listening vocabulary, its pronunciation will in turn evoke its meaning. In this way, even the occasional never-before-seen word may be read and understood with little or no outward sign or feeling of difficulty.

The automaticity of skillful readers' spelling-to-sound translations ensures that those many words of marginal visual familiarity will be recognized with the ease and speed required for fluent reading comprehension. Further, as the phonological translations serve to turn on both the word's meaning and its spelling, each encounter with the word strengthens direct spelling-to-meaning connections.

Phonological Translation and Comprehension. As it turns out, the value of automatic phonological translations extends beyond their service to the word-recognition process. Specifically, the language comprehension system is designed to work with whole, cohesive grammatical units—whole phrases or sentences—at once. Whether in listening or reading, the process through which it does so is much the same (Jarvella, 1971; Kleiman, 1975). In either case, the words of a message are presented and perceived one by one. And although they are tentatively interpreted on the fly, they are fully digested only afterward, when the clause or sentence is complete. In mystical deference to this process, speakers drop their pitch and pause at the end of every sentence; by dropping their pitch, they let their listeners know that it's time to interpret, and by pausing, they afford their listeners time to do so. Mimicking this rhythm, skillful readers are found to march their eyes through all the words of a sentence from beginning to end, and when they reach the period, they pause and think (Just & Carpenter, 1987).

Again, it is during these end-of-sentence pauses that listeners or readers actively construct and reflect on their interpretations, that they work out the collective meaning of the chain of words in memory and that meaning's contribution to their overall understanding of the conversation or text. Yet in order for this interpretive process to succeed, the whole clause or sentence must still exist, more or less intact, in the listener's or reader's memory when she or he is ready to work on it. So what does this have to do with phonological translations? A lot. Whereas the visual system is designed for encoding spatial patterns and transitions, the auditory system is designed for remembering ordered temporal patterns of information. Thus, by thinking or speaking the words to themselves, skillful readers effectively extend the longevity and holding capacity of their verbatim memory. Preventing skillful readers from subvocalizing does not impair their ability to interpret single familiar words or simple sentences; on the other hand, it severely disrupts their ability to remember or comprehend long or complex sentences (Baddeley, 1979; Levy, 1977, 1978; Waters, Caplan, & Hildebrandt, 1987). In keeping with this, you may notice that your own tendency to subvocalize becomes more noticeable when you are trying to read sentences that are especially long and difficult.

Even though this particular advantage of phonological translation has nothing to do with word identification per se, it points up one more reason the speed and effortlessness of the word-recognition process is so important. Auditory memory is highly sensitive to the pace with which information arrives (Dempster, 1981). If it takes a child too long to identify successive words, the beginning of the sentence will fade from memory before the end has been registered. Further, where a child is actively engaged in sounding out individual letters and syllables, the phonological processor is necessarily unavailable for retaining the wording of clauses. (For a discussion of the trade-offs between processing and storage demands in the reading situation, see Daneman & Tardif, 1987; Perfetti, 1985.)

Phonological Translations: A Once-Over. In sum, phonological translations are subservient to both reading and learning to read in a number of different ways. Most obviously, the capacity for phonological translations underlies the ability to "sound out" new words. Less obvious but of equal importance, where the sounding out process is reasonably fast and efficient, it serves powerfully to hasten the word's visual acquisition. Moreover, the benefits of this basic ability are no less valuable for mature readers than they are for beginners. In particular, it ensures that those many, many words of known meaning but limited visual familiarity can be recognized with the ease and speed required for reading with fluency and comprehension.

In this vein, it is worth noting that of the thousands upon thousands of different words that a skillful reader is expected to know, the vast majority are encountered very rarely. The person with an average daily diet of print would be lucky to have seen many of these words even once in a whole year's worth of reading. How many of these words would you lose, how many would fade away or blur together, if you depended on the strength and completeness of your visual memory alone? Finally, research shows that long and complex sentences cannot be understood without the mnemonic support gained through phonological translation.

The capacity for rapid, easy phonological translation has sometimes been dismissed as superfluous, optional, or even as a misguided or dysfunctional diversion of effort. Against these notions, insensitivity to the sounds of speech and difficulties in relating them to letters and spellings are found to be the single most frequent hole in the reading and language abilities of disabled readers of all ages (for reviews, see, e.g., Brady & Shankweiler, 1991; Carr & Levy, 1990; Stanovich, 1986). When given special instruction on breaking words into sounds and relating sounds to spellings, such readers generally do improve—sometimes dramatically (Blachman, 1987; Williams, 1979, 1980). Despite such help, however, Bruck (1992) has shown that, for many dyslexics, a core difficulty with spellings and sounds persists even into adulthood—and alongside, their reading continues to be slow and effortful.

In principle, the letters of an alphabetic script represent the phonemes of its language. Because of this, learning about spelling–sound relationships in a way that is useful for reading depends on phonemic awareness; that is, it depends on a conscious recognition that the sounds of words can be represented by a relatively small set of articulatory gestures, the phonemes.

Phonemic awareness is not natural. Instead, the ease with which people can gain conscious access to their phonological knowledge ranges broadly and appears to be determined, in part, by heredity (Olson et at., 1990). It is because of its difficulty for so many children that solid attention to the development of phonemic awareness is so vital a component of the preschool and primary classroom. Moreover, the pressing issue for the field of dyslexia at this time is the extent to which the elusiveness of its cure derives from the difficulties of trying

to turn off or displace an overlearned but self-limiting mode of perceiving text. To what extent would the syndrome go away if we could ensure that all children got off to the right start?

Summary

Relative to the overall literacy challenge, learning to recognize words really is a very small component. Yet it is also wholly necessary. In the end, the print on the page constitutes the basic perceptual data of reading. Rather than diverting efforts in search of meaning, the reader's letter- and word-wise processes supply the text-based information on which comprehension depends. As fluent readers move quickly and easily through the print, literal comprehension automatically unfolds apace.

But neither is literal comprehension the goal of reading. The full interpretation of a complex text may require retrieval of particular facts or events that were presented many pages earlier. It also may require consideration of knowledge and construction of arguments that are entirely extraneous to the text. And it certainly requires the critical and inferential activities necessary for putting such information together.

To be sure, it is this level of interpretation that we think of as true understanding. Yet interpretation at this level is not automatic; it requires active attention and can only be as fruitful as the effort and quality of thought that readers invest in it. But the effort and thought that readers can invest depends, in turn, on the ease and completeness with which they have executed the levels that support it. Deep and ready working knowledge of letters, spelling patterns, and words, and of the phonological translations of all three, is of inescapable importance to both skillful reading and its acquisition—not because it is the be-all or the end-all of the reading process, but because it enables it.

References

Adams, M.J. (1979a). Models of word recognition. *Cognitive Psychology, 11*, 133–176.

Adams, M.J. (1979b). Some differences between good and poor readers. In M.L. Kamil & A.J. Moe (Eds.), *Reading research: Studies and applications* (pp. 140–144). Clemson, SC: National Reading Conference.

Adams, M.J. (1981). What good is orthographic redundancy? In O.J.L. Tzeng & H. Singer (Eds.), *Perception of print* (pp. 197–221). Hillsdale, NJ: Erlbaum.

Adams, M.J. (1990). *Beginning to read: Thinking and learning about print.* Cambridge, MA: MIT Press.

Anderson, R.C., & Freebody, P. (1983). Reading comprehension and the assessment and acquisition of word knowledge. In B. Hutson (Ed.), *Advances in reading/language research* (pp. 231–256). Greenwich, CT: JAI Press.

Baddeley, A.D. (1979). Working memory and reading. In P. Kolers, E. Wrolstad, & H. Bouma (Eds.), *Processing of visible language* (Vol. 1). New York: Plenum.

Barron, R.W. (1981a). Development of visual word recognition: A review. In G.E. MacKinnon & T.G. Waller (Eds.), *Reading research: Advances in theory and practice* (Vol. 3, pp. 119–158). New York: Academic.

Barron, R.W. (1981b). Reading skill and reading strategies. In A.M. Lesgold & C.A. Perfetti (Eds.), *Interactive processes in reading* (pp. 299–328). Hillsdale, NJ: Erlbaum.

Bereiter, C. (1991). Implications of connectionism for thinking about rules. *Educational Researcher, 20*(3), 10–16.

Biemiller, A. (1970). The development of the use of graphic and contextual information as children learn to read. *Reading Research Quarterly, 6*, 75–96.

Blachman, B.A. (1987). An alternative classroom reading program for learning disabled and other low-achieving children. In W. Ellis (Ed.), *Intimacy with language: A forgotten basic in teacher education* (pp. 49–55). Baltimore: Orton Dyslexia Society.

Brady, S.A., & Shankweiler, D.P. (1991). *Phonological processes in literacy.* Hillsdale, NJ: Erlbaum.

Bruck, M. (1992). Persistence of dyslexics' phonological awareness deficits. *Developmental Psychology, 28*, 874–886.

Byrne, B. (1992). Studies in the acquisition procedure for reading: Rationale, hypotheses, and data. In P.B. Gough, L.C. Ehri, & R. Treiman (Eds.), *Reading acquisition* (pp. 1–34). Hillsdale, NJ: Erlbaum.

Carr, T.H., & Levy, B.A. (1990). *Reading and its development.* Hillsdale, NJ: Erlbaum.

Carroll, J.B., Davies, P., & Richman, B. (1971). *Word frequency book.* Boston: Houghton Mifflin.

Cattell, J.M. (1885). Über die Zeit der Erkennung und Benennung von Schriftzeichen, Bildern und Farben [The time it takes to recognize and name letters, pictures, and colors]. *Philosophische Studien, 2*, 635–650.

Daneman, M., & Tardif, T. (1987). Working memory and reading skill re-examined. In M. Coltheart (Ed.), *Attention and performance XII: The psychology of reading* (pp. 491–508). Hillsdale, NJ: Erlbaum.

Dempster, F.N. (1981). Memory span: Sources of individual and developmental differences. *Psychological Bulletin, 89*, 63–100.

De Zuniga, C.M., Humphreys, G.W., & Evett, L.J. (1991). Additive and interactive effects of repetition, degradation, and word frequency in the reading of handwriting. In D. Besner & G.W. Humphreys (Eds.), *Basic processes in reading* (pp. 10–33). Hillsdale, NJ: Erlbaum.

Downing, J. (1979). *Reading and reasoning.* New York: Springer-Verlag.

Estes, W.K. (1977). On the interaction of perception and memory in reading. In D. LaBerge & S.J. Samuels (Eds.), *Basic processes in reading* (pp. 1–25). Hillsdale, NJ: Erlbaum.

Fowler, C.A., Napps, S., & Feldman, L. (1985). Relations among regular and irregular morphologically related words in the lexicon as revealed by repetition priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 10*, 241–255.

Gough, P.B., Alford, J.A., & Holley-Wilcox, P. (1981). Words and contexts. In O.J.L. Tzeng & H. Singer (Eds.), *Perception of print* (pp. 85–102). Hillsdale, NJ: Erlbaum.

Jarvella, R. (1971). Syntactic processing of connected speech. *Journal of Verbal Learning and Verbal Behavior, 10*, 409–416.

Johnson, D.D., & Baumann, J.F. (1984). Word identification. In P.D. Pearson, R. Barr, M.L. Kamil, & P. Mosenthal (Eds.), *Handbook of reading research* (pp. 583–608). New York: Longman.

Juel, C. (1983). The development and use of mediated word identification. *Reading Research Quarterly, 18*, 306–327.

Juel, C. (1988). Learning to read and write: A longitudinal study of fifty-four children from first through fourth grade. *Journal of Educational Psychology, 80*, 437–447.

Juel, C. (1991). Beginning reading. In R. Barr, M.L. Kamil, P. Mosenthal, & P.D. Pearson (Eds.), *Handbook of reading research* (Vol. 2, pp. 759–788). White Plains, NY: Longman.

Juel, C., & Roper/Schneider, D. (1985). The influence of basal readers on first grade reading. *Reading Research Quarterly, 20*, 134–152.

Just, M.A., & Carpenter, P.A. (1987). *The psychology of reading and language comprehension.* Boston: Allyn & Bacon.

Kaye, D.B., & Sternberg, R.J. (1982). *The development of lexical decomposition ability.* Unpublished manuscript, Yale University, New Haven, CT.

Kleiman, G.M. (1975). Speech recoding in reading. *Journal of Verbal Learning and Verbal Behavior, 14*, 323–339.

Kučera, H., & Francis, W.N. (1967). *Computational analysis of present-day American English.* Providence, RI: Brown University Press.

Levy, B.A. (1977). Reading: Speech and meaning processes. *Journal of Verbal Learning and Verbal Behavior, 16*, 623–628.

Levy, B.A. (1978). Speech processes during reading. In A.M. Lesgold, S.W. Pellegrino, S.W. Fokkema, & R. Glaser (Eds.), *Cognitive psychology and instruction.* New York: Plenum.

Liberman, I.Y., Shankweiler, D., Orlando, C., Harris, K.S., & Berti, F.B. (1971). Letter confusions and reversals of sequence in the beginning reader: Implications for Orton's theory of developmental dyslexia. *Cortex, 7*, 127–142.

Manelis, L., & Tharp, D. (1977). The processing of affixed words. *Memory and Cognition, 5*, 690–695.

Masonheimer, P.E., Drum, P.A., & Ehri, L.C. (1984). Does environmental print identification lead children into word reading? *Journal of Reading Behavior, 16*, 257–271.

Mayzner, M.S., & Tresselt, M.E. (1965). Tables of single-letter and digram frequency-counts for various word-length and letter position combinations. *Psychonomic Monograph Supplements, 1*, 13–32.

McClelland, J.L., & Elman, J.L. (1986). The TRACE model of speech perception. *Cognitive Psychology, 18*, 1–86.

McClelland, J.L., & Rumelhart, D.E. (1981). An interactive activation model of context effects in letter perception: Part 1, an account of basic findings. *Psychological Review, 88*, 373–407.

McConkie, G.W., & Zola, D. (1981). Language constraints and the functional stimulus in reading. In A.M. Lesgold & C.A. Perfetti (Eds.), *Interactive processes in reading* (pp. 155–175). Hillsdale, NJ: Erlbaum.

McKeown, M.G., Beck, I.L., Omanson, R.C., & Pople, M.T. (1985). Some effects of the nature and frequency of vocabulary instruction on the knowledge and use of words. *Reading Research Quarterly, 20*, 522–535.

Mewhort, D.J.K., & Campbell, A.J. (1981). Toward a model of skilled reading: An analysis of performance in tachistoscopic tasks. In G.E. MacKinnon & T.G. Waller (Eds.), *Reading research: Advances in theory and practice* (Vol. 3, pp. 39–118). New York: Academic.

Miller, G.A., & Gildea, P.M. (1987): How children learn words. *Scientific American, 257*(3), 94–99.

Nagy, W.E., Anderson, R.C., & Herman, P.A. (1987). Learning word meanings from context during normal reading. *American Educational Research Journal, 24*, 237–270.

Nagy, W.E., Herman, P.A., & Anderson, R.C. (1985). Learning words from context. *Reading Research Quarterly, 20*, 233–253.

Olson, R., Wise, B., Conners, F., & Rack, J. (1990). Organization, heritability, and remediation of component word recognition and language skills in disabled readers. In T.H. Carr & B.A. Levy (Eds.), *Reading and its development* (pp. 261–322). Hillsdale, NJ: Erlbaum.

O'Rourke, J.P. (1974). *Toward a science of vocabulary development*. The Hague, the Netherlands: Mouton.

Otterman, L.M. (1955). The value of teaching prefixes and word-roots. *Journal of Educational Research, 48*, 611–616.

Patterson, K.E., & Coltheart, V. (1987). Phonological processes in reading: A tutorial review. In M. Coltheart (Ed.), *Attention and performance XII: The psychology of reading*, Hillsdale, NJ: Erlbaum.

Perfetti, C.A. (1985). *Reading ability*. New York: Oxford University Press.

Perfetti, C.A., Bell, L.C., & Delaney, S.M. (1988). Automatic (prelexical) phonetic activation in silent word reading: Evidence from backward masking. *Journal of Memory and Language, 27*, 1–22.

Rayner, K., & Pollatsek, A. (1987). Eye movements in reading: A tutorial review. In M. Coltheart (Ed.), *Attention and performance XII: The psychology of reading* (pp. 327–362). Hillsdale, NJ: Erlbaum.

Rumelhart, D.E., & McClelland, J.L. (1986). On learning the past tenses of English verbs. In J.L. McClelland & D.E. Rumelhart (Eds.), *Parallel distributed processing, Vol. 2: Psychological and biological models* (pp. 216–271). Cambridge, MA: MIT Press.

Seidenberg, M.S. (1987). Sublexical structures in visual word recognition: Access units or orthographic redundancy. In M. Coltheart (Ed.), *Attention and performance XII: The psychology of reading* (pp. 245–263). Hillsdale, NJ: Erlbaum.

Seidenberg, M.S., & McClelland, J.L. (1989). A distributed, developmental model of word recognition and naming. *Psychological Review, 96*, 523–568.

Seidenberg, M.S., Tannenhaus, M.K., Leiman, J.M., & Bienkowski, M. (1982). Automatic access of the meanings of ambiguous words in context: Some limitations of knowledge-based processing. *Cognitive Psychology, 14*, 489–537.

Spoehr, K.T. (1981). Word recognition in speech and reading: Toward a theory of language processing. In P.D. Eimas & J.L. Miller (Eds.), *Perspectives on the study of speech*. Hillsdale, NJ: Erlbaum.

Stahl, S.A., & Fairbanks, M.M. (1986). The effects of vocabulary instruction: A model-based meta-analysis. *Review of Educational Research, 56*(1), 72–110.

Stanovich, K.E. (1980). Toward an interactive-compensatory model of individual differences in the development of reading fluency. *Reading Research Quarterly, 16*, 32–71.

Stanovich, K.E. (1984). The interactive-compensatory model of reading: A confluence of developmental, experimental, and educational psychology. *Remedial and Special Education, 5*, 11–19.

Stanovich, K.E. (1986). Matthew effects in reading: Some consequences of individual differences in the acquisition of literacy. *Reading Research Quarterly, 21*, 360–406.

Stanovich, K.E. (1993). Does reading make you smarter? Literacy and the development of verbal intelligence. In H. Reese (Ed.), *Advances in child development and behavior* (Vol. 24). New York: Academic.

Taft, M. (1985). The decoding of words in lexical access: A review of the morphographic approach. In D. Besner, T.G. Waller, & G.E. MacKinnon (Eds.), *Reading research: Advances in theory and practice* (Vol. 5). New York: Academic.

Tannenhaus, M.K., Flanigan, H., & Seidenberg, M.S. (1980). Orthographic and phonological code activation in auditory and visual word recognition. *Memory and Cognition, 8*, 513–520.

Tyler, A., & Nagy, W.E. (1987). *Use of derivational morphology during reading*. Unpublished manuscript, University of Illinois, Champaign.

VanOrden, G.C. (1991). Phonologic mediation is fundamental to reading. In D. Besner & G.W. Humphreys (Eds.), *Basic processes in reading* (pp. 77–103). Hillsdale, NJ: Erlbaum.

Vellutino, F.R. (1991). Introduction to three studies on reading acquisition: Convergent findings on theoretical foundations of code-oriented versus whole-language approaches to reading instruction. *Journal of Educational Psychology, 83*, 437–443.

Vernon, M.D. (1971). *Reading and its difficulties*. Cambridge, UK: Cambridge University Press.

Waters, G., Caplan, D., & Hildebrandt, N. (1987). Working memory and written sentence comprehension. In M. Coltheart (Ed.), *Attention and performance XII: The psychology of reading* (pp. 531–555). Hillsdale, NJ: Erlbaum.

Weber, R.M. (1970). First graders' use of grammatical context in reading. In H. Levin & J.P. Williams (Eds.), *Basic studies on reading* (pp. 147–163). New York: Basic.

Williams, J.P. (1979). The ABD's of reading: A program for the learning disabled. In L.A. Resnick & P.A. Weaver (Eds.), *Theory and practice of early reading* (Vol. 3, pp. 227–259). Hillsdale, NJ: Erlbaum.

Williams, J.P. (1980). Teaching decoding with a special emphasis on phoneme analysis and phoneme blending. *Journal of Educational Psychology, 72*, 1–15.

Woodworth, R.A. (1938). *Experimental psychology*. New York: Henry Holt.